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Mathematical achievement and critical thinking skills in asynchronous discussion forums

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Abstract

The connection between critical thinking (CT) skills and mathematics scores of students of an engineering mathematics unit is explored in this paper through two batches of students. The DF postings resulting from participation in two online Discussion Forum (DF) problem solving sessions were analyzed for CT skills through CAIS model and a weighted CT score was given to each student. Mathematical achievement was measured through final examination scores, and initial mathematics ability was measured through an initial test. A significant linear relationship was observed between CT and mathematical achievement. The initial mathematics ability and CT scores showed a significant linear relationship only for one batch of participants. The study concluded that CT skills, when properly encouraged, could result in improvement in mathematical achievement.

*Keywords:*Critical Thinking skills, Initial mathematics ability, Mathematical achievement, Online Discussion Forums

Introduction

Mathematics and Critical Thinking (CT) cannot be separated from each other, if meaningful learning of mathematics is sought after (Innabi & Sheikh, 2006; Aizikovitsh & Amit, 2010). Hence, teaching CT in mathematics classes should be a goal of mathematics educators. Garrison, Anderson and Archer (2001) and Schrire (2006) rightly say that CT is both a process and an outcome. As an outcome, it is best understood from an individual perspective through the acquisition of deep and meaningful understanding as well as content-specific critical inquiry abilities, skills, and dispositions. As a product, CT is, perhaps, best judged through individual educational assignments, but it is a complex and (only indirectly) accessible cognitive process (Garrison et al., 2001; Schrire, 2006). A concise definition of CT adopted in this study is “the ability to use acquired knowledge in flexible and meaningful ways, through understanding the problem or issue, evaluating evidence, considering multiple perspectives, and taking a position” (Vanderstoep & Pintrich, 2003, p. 275). Online learning management systems like Blackboard, WebCT, and Moodle provide avenues for online asynchronous discussions also known as discussion forums (DFs). Research has shown the potential of DFs for creating an educational community of inquiry and mediating critical reflection and discourse, to support higher-order constructivist learning and the development of a learning community (Levine, 2007).The term “online Discussion Forum” or ODF in this study was used to mean “asynchronous online learning forum” available under the Blackboard Learning System (An, Shin, & Lim, 2009). Student performance in mathematics, referred to as mathematical achievement, has been taken as a relevant dependent variable in this research study. The relationship between the quality of online communication and

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mathematical achievement has been the subject of many studies like those of Beaudrie (2000) and Kosiak (2004). The research questions addressed in this paper are: (1) Was there a relationship between the level of CT in the ODFs and initial mathematics ability? (2) Was there a relationship between the level of Critical Thinking in the ODFs and mathematical achievement?

1. Research Study

The course involved in this study was the compulsory first semester engineering mathematics unit, of the Bachelor of Engineering programme offered by Swinburne University of Technology, Sarawak Campus in Malaysia. The data was collected from two batches of students of the same unit, Batch 1(43 participants) and Batch 2(60 participants). The first year university students needed a lot of support in terms of coping up with new learning environments and taking ownership of their learning. The ODFs available on the Blackboard were used as a means of establishing good rapport between the students and the lecturer. All these participants were new to the experience of using online DFs in the educational setting. Two problem solving sessions were planned on these DFs with ill-structured problems posted at two different times (Week 4 and Week 10 respectively) during the 14-week long course. The goal of these sessions was for students to work collaboratively to solve and develop critical thinking/problem solving based on application problems (M-S Chiu, 2009). The first forum (DF1) carried a weightage of 7%, and the second forum (DF2) carried a weightage of 8% to encourage active participation. The ODFs happened in heterogenous groups of high, medium and low scoring students of mathematics, based on an initial test given in the first week of the semester. Students participated in discussion sessions over the ODF available through the Blackboard to supplement their typical class meeting times. The instructor encouraged these collaborative sessions by moderating (scaffolding) the discussion thread in order to stimulate both mathematical learning and mathematical understanding. The study used the infusion approach (Aizikovitsh-Udi &Amit, 2011) of fostering CT skills, by embedding the teaching of the skills through the ODFs. Data was collected in this study using various modes: (1) The ODF postings; (2) Initial mathematics scores; and (3) Final examination scores.

2. Results

The ODF postings, collected from the two problem solving DF sessions (coded as DF1 and DF2) were believed to be reflective of the CT processes adopted by the participants during these sessions. The content analysis of the postings in the current study was done using the CAIS model. CAIS is an acronym which represented the categories (phases) of CT, namely Clarification, Assessment, Inference and Strategies. The CAIS model (Jacob & Sam, 2010) in Table 1, was adapted by the researcher based on two models – one was the model proposed and tested by Perkins and Murphy (2006), and the other was the framework for assessing CT developed by Paul and Elder (2006).

Table 1. CAIS Model to Measure CT during Online DF Sessions in Mathematics (Jacob & Sam, 2010)

Clarification - Formulates the problem precisely and clearly *(The different indicators are shown in columns)*			
Analyses, negotiates or discusses the scope of the problem	Identifies one or more underlying assumptions in the parts of the problem	Identifies relationships among the different parts of the problem	Defines or criticizes the definition of relevant terms
Assessment - Raises vital questions and problems within the problem *(The different indicators are shown in columns)*			
Gathers and assesses relevant information.	Provides or asks for reasons that proffered evidence is valid or relevant.	Make value judgment on the assessment criteria or argument or situation.	
Inference - Reasons out based on relevant criteria and standards *(The different indicators are shown in columns)*			
Makes appropriate deductions from discussed results.	Arrives at well thought out conclusions	Makes generalizations from relevant results.	Frames relationships among the different parts of the problem.
Strategies - Thinks and suggests open mindedly within alternative systems of thought. *(The different indicators are shown in columns)*			
Propose specific steps to lead to the solution.	Discuss possible steps.	Evaluate possible steps.	Predicts outcomes of proposed steps.

After preparing the lists of categories, rules of inclusion, and examples, the researcher and a second coder met to compare their categorisation of the postings and discussed any discrepancies in classification. After this initial training, the researcher and the second coder then coded the postings for 10% of the messages, to obtain the inter-coder reliability. The results of the researcher and the coder were evaluated for inter-coder agreement (De Wever, Schellens, Valcke, & Van Keer, 2006) using the formulae (Anderson, Rourke, Garrison & Archer, 2001; Garrison, et al., 2001):

Inter-coder agreement = (Number of agreements)/ (Total number of agreements and disagreements)
Cohen's kappa = fo - fc) /(N - fc)
N = the total number of judgements made by each coder
fo = the number of judgements on which the coders agree
fc = the number of judgements on which agreement is expected by chance

The inter-coder agreement for the 47 postings tested for agreement of the online DF was 0.89 using percent agreement, and 0.85using Cohen's Kappa.

Also a weighted CT score was associated with every participant based on the classification of the postings, as shown in Table 2. Different weights were associated with the different categories to distinguish between the different levels of CT skills, in order that the score reflects the level of the CT skill of the participant. The scoring table in Table 2 was developed based on the following principles: (1) the limits of the number of postings were set, assuming the average number of postings of a participant, per category, for one DF was around three, (2) higher weights were associated with the phases, inference and strategies, to indicate the higher levels of CT, and (3) the maximum weightage of one category differed by one from the minimum weightage of the next category. Hence, the maximum score possible was 20, if a participant had more than four postings in all categories.

Table 2. Scoring Table for the CT Categories

Category	No. of postings	Weightage
	1-2	1
Clarification	3-4	1.5
	>4	2
	1-2	3
Assessment	3-4	3.5
	>4	4
	1-2	5
Inference	3-4	5.5
	>4	6
	1-2	7
Strategies	3-4	7.5
	>4	8

Table 3. Descriptive Statistics of the CAIS model scores

	Batch 1 (N = 43)					Batch 2 (N = 60)				
CAIS model score	Mean	S.D.	Q1	Q2	Q3	Mean	S.D.	Q1	Q2	Q3
CT1	6.56	5.230	1.00	4.5	10.50	8.33	6.045	4.00	7.00	12.00
CT2	11.36	5.302	9.00	12.00	16.50	8.76	5.112	4.50	9.50	14.25

In Batch 1 and Batch 2, there was an improvement in the CAIS model scores, as seen from the mean scores for CT1 and for CT2 in Table 3. The median (Q2) score for CT2 in Batch 2 has gone up to 9.50 from 7 for CT1. But CT1 and CT2 had comparatively large S.D. values (6.045 and 5.112 for Batch 2) against the mean values (8.33 and 8.76 for Batch 2). Thus, though the average CAIS model scores have increased, the variability of the scores also increased. It is also noticed that CT skills exhibited were not in the higher categories of Inference and Strategies, the mean score being only between 8-11 for both batches. The maximum score possible was 20, which would happen only if the student participants had many postings in the higher categories. Thus the CT skills exhibited by the majority of the participants through the problem solving sessions were in the lower levels of CT. The Q3 values of CT1 and CT2 indicated that only 25% of the Batch 2 participants crossed the score of 12 and 14.25.

The researcher looked into the variability noticed in the distribution of CT1 and CT2 scores, whereby only a minority of participants scored in the higher range of 15-20, 20 being the maximum possible score. A correlation analysis was done between the initial mathematics ability of the participants, measured using the initial quiz scores (marks of the quiz paper given in the first week of the 14-week semester) and the CAIS model scores from DF1 and DF2 (namely, CT1 and CT2). For Batch 1, the initial quiz scores (out of 100) had an average of 29.9, standard deviation of 14.4 marks and inter quartile range of 20 marks. No significant correlation was observed between the initial mathematics ability and the CAIS model scores from DF1 (Pearson moment correlation coefficient, $r = .208$, $p = 0.182$) and DF2 (Pearson moment correlation coefficient, $r = .222$, $p = 0.152$).For Batch 2, the initial quiz scores (out of 100) had an average of 35.9, standard deviation of 14.2 and inter quartile range of 19.2. Similarly, no significant correlation was observed between the initial mathematics ability and the CAIS model scores from DF1 (Pearson moment correlation coefficient, $r = .246$, $p = 0.058$). But the correlation proved significant between the initial mathematics scores and the CAIS model scores from DF2 (Pearson moment correlation coefficient, $r = .323$, $p = 0.012$). The result implied that those participants, who had entered the unit with a good mathematics ability (as reflected in the initial quiz marks), exhibited comparatively good CT skills (higher CT2 scores) in DF2. The variability in CAIS model scores in Batch 2 could be attributed to the comparatively varied ability in mathematics, as shown by the initial quiz scores. Thus, it was noticed that the initial mathematics ability of the participants seemed to be related to the phase of CT to which they belonged to, as per the CAIS model.

The variable mathematical achievement was measured using the final examination scores at the end of the 14-week semester, of the participants. The descriptive statistics of the final examination scores are shown in Table 4.

Table 4. Descriptive Statistics of the Final Examination scores

	Minimum	**Maximum**	**Mean**	**S.D.**
Batch 1 (N=43)	25.50	86.50	57.87	16.882
Batch 2 (N=60)	8.50	93	62.59	17.23

A correlation analysis was performed between the dependent variable mathematical achievement and the independent variables which were the CAIS model scores, namely, CT1 and CT2. The normality assumption for the data could be overridden because of the large sample size (Norussis, 2004). The correlation analysis could be observed from Table 4.12. In Batch 1, CT1 was found to have no significant correlation with mathematical achievement ($r = .131$, $p = 0.402$). But CT2 was significantly correlated with mathematical achievement ($r = .324$, $p = 0.034$). In Batch 2, CT1 and CT2 were both correlated with mathematical achievement, with Pearson's correlation of .517 ($p < 0.005$) and .644 ($p = 0.003$) respectively. The results could be observed in detail from Table 5.

Table 5. Correlation between Final Examination scores and CAIS Model scores

	Batch 1 (N = 43)		Batch 2 (N = 60)	
	CT1	CT2	CT1	CT2
Final exam score	$r = .131$ ($p = 0.402$)	$r = .324$ ($p = 0.034$)	$r = .517$ ($p = 0.000$)	$r = .376$ ($p = 0.003$)

Thus, mathematical achievement of the participants was found to be significantly correlated with the CAIS model scores. Since the CAIS model score is a quantitative indicator of CT in the participants in the context of online DFs, it could be concluded that CT exhibited in the online DFs and mathematical achievement were related.

3. Discussions and Conclusions

CT skills could be encouraged over the problem solving sessions in engineering mathematics over the ODFs, though the level of CT exhibited was in the lower categories of CT (Jacob & Sam, 2008). Studies done by De Leng, Dolmans, Jobsis, Muijtjens, and Van der Vleuten(2009), Kanuka, Rourke and Laflamme (2007), and Schrire (2004, 2006) using Garrison's Practical Inquiry Model, to measure the quality of ODF postings or messages, yielded similarly small percentage of higher order thinking (referred to as critical thinking or CT in this study The findings of this study indicated that the initial mathematics ability of the students could play a role in determining the level of CT in mathematics to which they could be raised to perform in the ODFs. Although the majority of the participants were thinking critically to some degree, comparatively few postings were found to reflect high levels of CT. The mathematical achievement of the students, measured using the final examination scores, was found to be significantly correlated with the CAIS model scores reflecting the CT skills of the students. The students who have exhibited fairly good CT skills have fared well in the final examination too. CT skills, when properly encouraged could result in improvement in mathematical achievement. Thus it is worth investing time to encourage CT skills, which will in turn help to improve the course results and the university stakeholders. CT skills were reported by Kosiak (2004), to be correlated with mathematics examination scores, in her study on online problem solving sessions for college algebra. CT skills and academic achievement have been shown to be significantly related by Semerci (2005). The relationship between CT skills in ODFs and mathematical achievement has not received much attention in literature; hence a detailed discussion is not possible. Emir (2009) reported that academic achievement had no impact on CT. Given such varied results on the connection between academic achievement and CT, it was worth examining the relationship between academic achievement in mathematics, and CT skills. In line with the requirements of the higher education bodies in relation to mathematics skills of graduates, and based on the expectations and necessity of CT competencies in new graduates, the study of CT must continue. Research on ODFs to facilitate CT in teaching and learning could be an area to dig in further for mathematics and non-mathematics educators and researchers.

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